POTENTIAL EFFECTS OF AUTOMATIC CRASH NOTIFICATION (ACN) ON AIR MEDICAL SERVICES: TRAUMA SCENE TRANSPORT UTILIZATION PATTERNS

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ABSTRACT

The availability of automatic crash notification (ACN) systems is increasing. First generation systems that are available today provide crash notification and vehicle location in the event of a frontal crash in which airbag deployment occurs. Advanced systems will soon be available that are capable of detecting a variety of crashes and reporting the character and severity of the crash. An as yet uninvestigated area concerns how ACN-provided information can be used effectively by the emergency medical services system. Of particular interest is the potential synergy between advanced ACN systems and more effective utilization of helicopter emergency medical services (HEMS) for trauma scene transports. This paper reports on the patterns of ground ambulance and HEMS trauma scene transports for patients injured in motor vehicle crashes that occurred in Erie County, New York. These data were used to determine if observed transport patterns were consistent with areas previously identified as the most time efficient for trauma patient transport by HEMS. Additional analyses were conducted to determine the potential effect of ACN data on the definition and refinement of areas identified as the most time efficient for HEMS transport. In particular, the transport data timelines were examined to identify the affect on total prehospital time of putting the helicopter on standby based on the more timely crash notification and severity information provided by advanced ACN systems.

INTRODUCTION

It is generally accepted that minimized total prehospital time (i.e., time from injury until arrival in a receiving facility) is an important factor for trauma patient survival, since timely arrival at a trauma center may reduce trauma patient morbidity and mortality. Because helicopters travel at higher speeds and follow more direct routes than ground ambulances, helicopter emergency medical services (HEMS) may, in some situations, reduce total prehospital time by shortening the transport time. However, this advantage is not universal and in some situations it may not be more time efficient to transport by HEMS. The HEMS time advantage can be lost because of the additional time required to request HEMS services, to prepare for flight, to travel the distance from the helicopter base to the injury location and, in some cases, to move the patient from the injury site to the helicopter landing site. This is particularly true when patients can be prepared quickly for ground ambulance transport .[1]

Generally, the benefit of helicopter transport is a reduction in transport time.[2,3] If there is no reduction in total prehospital time, transport by HEMS offers little advantage over ground ambulance transport if the care providers are similarly trained. Intuitively, the time to actually transport a patient from any location to the trauma center will always be shorter for a helicopter. However, delay in notifying the helicopter as well as any additional time necessary to complete helicopter-specific tasks, may negate any timesaving from helicopter transport. Thus, in some locations ground ambulance transport to a trauma center may be more time efficient, especially if ground ambulance departure from the scene can be initiated significantly sooner than helicopter departure.

Billittier, et. al. found that providers frequently failed to select the most appropriate triage, transportation, and destination decision when given a hypothetical scenario.[4] This prompted the creation of better guidelines to assist providers in making the difficult decision of whether to transport by ground ambulance or HEMS. These guidelines were created for Erie County, New York and were based upon a geographic model that illustrated the locations from which HEMS transport was more efficient. The guidelines were published in 1999.[5] Figure 1 illustrates a summary of the guidelines that were created. Shown on the figure is a map of Erie County with the location of the level 1 adult trauma center (i.e., the Erie County Medical Center) and the HEMS base (i.e., Mercy Flight of Western New York) that served the region. The shaded areas on the map indicate the general regions in the county where it was found to be more time efficient to transport a

Figure 1. Outline of Erie County with the area where it is more time efficient to transport by ground ambulance shown in yellow. Theoretical flight time contours of 10, 15 and 20 minutes are shown for flights from the HEMS base to the crash scenes and then to the level one adult trauma center.

patient via ground ambulance than HEMS. For reference, theoretical flight time contours of 10 (red), 15 (orange), and 20 (green) minutes are also shown for flights from the HEMS base to the crash scene and then to the level 1 adult regional trauma center.

Initial testing of the automatic crash notification (ACN) systems was done in Western New York by Veridian Engineering.[6] This test provided data to compare the time of crash notification by ACN to the time a witness notified the 9-1-1 dispatch center that a crash had occurred. For the crashes that occurred during this test, it was found that in thirteen of the fifteen crashes, the ACN system reduced the crash notification times by between 0.3 and 17 minutes, with an average of 3.3 minutes. First generation ACN systems are widely available today and they can provide 9-1-1 dispatch centers with early crash notification and vehicle location information in the event of a frontal crash in which the airbag deploys. In the near future, more advanced systems will be available that are capable of detecting a wider variety of crashes and reporting the character

and severity of the crash. Information provided by advanced ACN systems, when used effectively by the emergency medical services system, could have a greater impact on reducing total prehospital time than just the reduction in time resulting from automatic crash notification. Several potential benefits of the advanced ACN information have been identified, including: assisting dispatchers and emergency medical service personnel in identifying patients who meet trauma triage criteria, speeding the process of emergency medical services dispatch, and enabling a more informed decision regarding the appropriate mode of transport (e.g., ground ambulance versus helicopter emergency medical services). These benefits could greatly reduce the time to HEMS arrival and would consequently reduce the total prehospital time (Figure 2). Utilizing findings of the ACN test performed in Western New York, this paper explores how early identification of a motor vehicle crash occupant requiring treatment at a level 1 adult regional trauma center could be used to identify the most time efficient means of trauma patient transport. Specifically, we considered the effect of putting HEMS on stand-by when the ACN crash message is received at the 9-1-1 dispatch center. The literature suggests that 3 to 10 minutes can be saved in total prehospital time by earlier notification of HEMS services so that flight preparations can be made.[4] For this analysis we assumed that 5 minutes of total prehospital time would be saved through early notification.

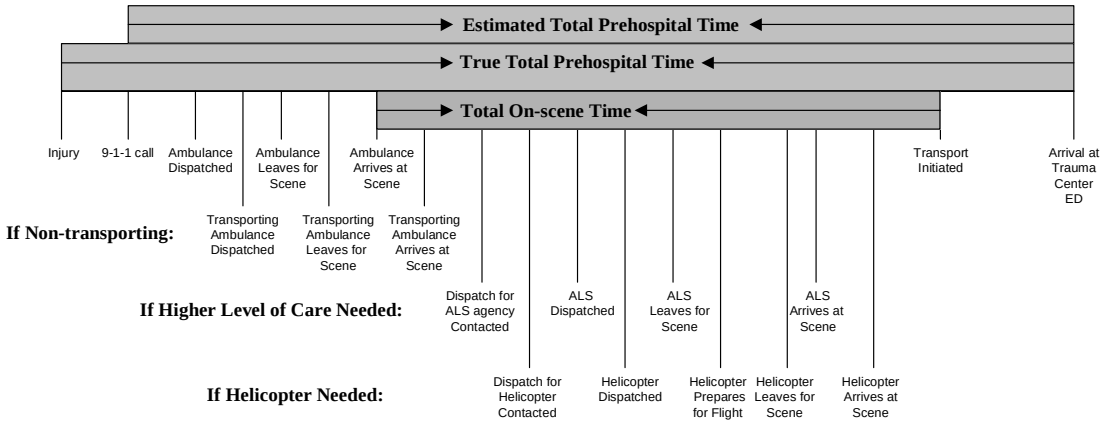

Figure 2. Components of Total Prehospital Time.

Objective

The objectives of this analysis were: (1) to determine if motor vehicle crash occupants were being transported by EMS in the most time efficient manner based on a previous geographic analysis, (2) to determine if patients who died from their injuries at the hospital were more often transported by the least time efficient means, and (3) to evaluate the affect of an ACN derived 5 minute decrease in HEMS total prehospital time on the areas identified as being the most time efficient for HEMS transport.

METHODS

Study Design

A retrospective review of adult motor vehicle crash occupants that were injured in Erie County, New York was conducted. Current data was superimposed on previously created maps of Erie County showing the most time efficient mode of transport. The methods used to create these maps were described previously.[5]

Study Setting and Population

Erie County covers 1,044 square miles and has a population 950,000 people.[7] It is composed of rural, suburban, and urban areas. It is served by a single level one adult regional trauma center and a level one pediatric regional trauma center. The adult trauma center is a 389 bed tertiary teaching facility with approximately 15,000 admissions annually, of which 1,800 are for trauma. Local trauma triage guidelines are based on those of the American College of Surgeons Committee on Trauma and require that trauma patients, identified by physiologic and mechanism of injury criteria, be transported directly to the trauma center if the transport time will be less than 30 minutes. These guidelines dictate that HEMS can be used if it will significantly reduce arrival time at the trauma center.

The emergency medical services system is composed of a combination of volunteer, municipal, and commercial services. These services operate as stand alone agencies or part of a fire department. Some of them provide patient transport and some stabilize the patient until a transporting service arrives. Their level of care ranges from basic life support to advanced life support and all services utilize the same regional treatment protocols. One HEMS agency serves the county. This service has two medically modified helicopters stationed within the county and at least one is in service at all times. The HEMS base is approximately 10 miles south of the trauma center as shown in Figure 1.

Inclusion/Exclusion Criteria

All patients injured in a motor vehicle crash between November 1996 and October 2000 were eligible for study inclusion. These patients had to be transported by emergency medical services directly to the adult level 1 regional trauma center in Erie County and information about their injuries and treatment had to have been entered into the trauma registry. This means that patients who were transferred from other hospitals to the trauma center or who were not admitted to the hospital for further treatment were not included in the study.

The trauma registry includes only those patients who were admitted to the trauma center for their injuries or died of their injuries in the emergency department. People who died at the scene of their crash were not included in the study. Motor vehicle crash occupants were identified through e-codes. Patients were included if they had been assigned motor vehicle crash primary e-codes 810-816, 819 or 821-823 and only those patients with an e-code ending with .0 or .1 were included in the study. This insured that only occupants of a motor vehicle that was involved in a crash were included. For example, pedestrians struck by vehicles and carbon monoxide poisonings were not included.

Data on crash location was obtained from a separate database of police accident reports (i.e., DMV 104s). Both datasets were anonymous. Therefore, trauma registry patients who could not be matched to an entry in the database of police accident reports were not included since crash location could not be identified.

Trauma Registry Data

An anonymous data set was obtained from the adult level 1 regional trauma center's trauma registry. A single registrar obtained patient data by reviewing the patient's medical record after they were discharged and then abstracted this information into the trauma registry. The trauma registry utilized a commercially available database for data entry and storage. Data obtained from the registry for this analysis included the date and time of admission to the emergency department, the patient's age, gender, mode of transport to the emergency department, e-code, and final disposition (i.e., lived versus died).

Police Accident Report Data

An anonymous data set was obtained from the County of Erie Department of Central Police Services for all crashes that occurred during the study period in which at least one occupant was injured and transported to a receiving facility by emergency medical services. This data set was derived from a database that was created by encoding the handwritten police accident report completed by a police officer at the time of a crash. Data obtained for this study included date, time, and location of the crash; as well as the age, gender, and position in the vehicle for each injured occupant. The database included police accident reports from all municipalities and districts within Erie County except for the following: Cities of Lackawanna and Tonawanda, Villages of Gowanda, Williamsville and Farnham and the Town of Amherst. These excluded areas represent approximately 6% of the area of Erie County and 16% of the county's population.

Matching

Trauma registry and police accident report data were hand matched by a single person (EBL) based on the hour of the day, date, and town where the crash occurred and the injured persons age,

position in the vehicle, and gender. The date of the crash was required to be an exact match for all patients included in the study. The patient's gender and age were also required to be an exact match unless the police report listed the age as 0. In that case the age was considered to be missing and if the remaining fields matched the two records were considered to be for the same person. In some cases the hour of day was not an exact match. If they were within one hour of each other the records were considered to match. However, if they were more than an hour different the records were considered to match but were denoted as not being a "perfect" match. These records were still considered to be matched cases and were used in the analysis. The crash locations were obtained from the police accident report data set and for the matched cases were added to the patient's registry data.

Geographic Analysis

Crash locations were geographically coded (geocoded) on a map of Erie County that illustrated the most time efficient transport mode for each geographic location. When no cross street was given, the middle of the street was chosen as the motor vehicle crash location. This map was used to identify how frequently the most time efficient mode of transport was used. Motor vehicle crash occupants who died at the hospital from their injuries were identified to determine if they were more frequently transported by the least efficient means of transport.

The maps were also adjusted to analyze the potential effect that advanced ACN technology might have had on total prehospital time. It was estimated that if HEMS were put on stand-by at the time ACN notified the dispatch center of a crash, approximately 5 minutes in total prehospital time would have been saved for patients transported by HEMS. This estimate was used to adjust the shape of the area where it was determined in the previous study that transport by ground ambulance would be more time efficient.

As in the previous study, Environmental Systems Research Institute (ESRI) ArcView and extension Spatial Analyst (Redlands, CA) were used to analyze total prehospital times and injury locations. A reference map of all injury locations was created with total prehospital times plotted on the z-coordinate. Two contour surfaces describing total prehospital time were then interpolated; one for ground ambulance transports and one for HEMS transports. The map calculator was used to determine where HEMS transport contours minus 5 minutes were lower than ground ambulance contours indicating that HEMS transport would be more time efficient from those locations. The remaining area was considered to be more time efficient for ground ambulance transport. This ground ambulance transport area was then compared to the previously identified ground ambulance transport area where the 5 minute total prehospital time reduction was not considered. The intent was to determine how the shape of the area changed and how many additional patients HEMS would have transported.

Data Analysis

Descriptive statistics were used to describe the percent of patients transported by the most time efficient mode of transport given their location. Time efficient was used to denote the area where, based upon the earlier empirical analyses, the form of transport used would have the shortest total prehospital time. Chi Square or Fisher's Exact Test was used to determine if there was a difference in mortality for those patients transported by the most time efficient means. Approximately 6% of patients in the trauma registry ultimately died of their injuries. Therefore, to obtain a power of 0.8 with an alpha of 0.05 to detect a 10% higher death rate among those transported by a means considered to be less time efficient required 168 patients in each group.

RESULTS

There were 1,356 calls in the trauma registry that had a motor vehicle crash e-code, were within Erie County, were transported by HEMS or ground ambulance, and were taken directly to the level 1 adult regional trauma center. Using date, hour of day, age, town, seating position and gender, 648 trauma registry patients were perfectly matched to the police accident report database and the crash location was obtained. An additional 105 registry patients were matched to the police accident report database but had some slight variation in the hour of the day in which the crash occurred or the age of the injured person. Therefore, data for a total to 753 patients was available for analysis.

Based upon location information from the police accident report database, ninety-eight percent (740) of the matched data was able to be geocoded. Eleven of the 13 crash locations that could not be plotted were considered to be perfect matches. Table 1 compares the actual patient transport mode to the mode of transport that was identified as the most time efficient for the location where the crash occurred.

Table 1.
Comparison of actual patient transport mode with the type of transport considered most time efficient for the crash location

Actual Patient Transport Mode	Ground Ambulance Most Time Efficient	HEMS Most Time Efficient
Ground Ambulance	446	180
HEMS	16	98

Three percent of patients were transported by HEMS from crash sites that were in areas where ground ambulance transport was identified as the most time efficient and 35% of patients were transported by HEMS in areas where HEMS transport was identified as the most time efficient. Overall, 74% of patients were transported by the form of transport considered to provide the shortest total prehospital time for the crash location.

Figure 3 shows a map of Erie County with the location of the level 1 adult regional trauma center and the HEMS base marked. The yellow area on the map indicates the general regions in the county where it was more time efficient to transport a patient via ground ambulance compared to HEMS. Each motor vehicle crash is represented by a symbol. The red triangles represent those patients who were transported by HEMS and black squares represent those patients transported by ground ambulance.

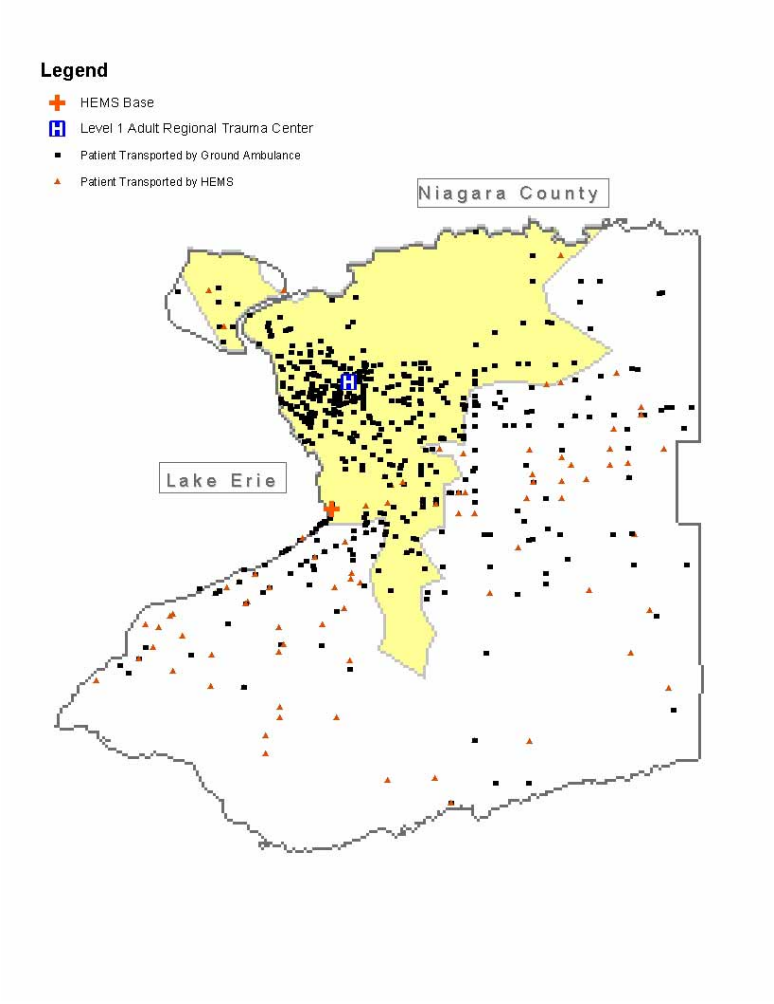

Figure 3. Outline of Erie County with the area where it is more time efficient to transport by ground ambulance shown in yellow. Motor vehicle crash locations are illustrated by transport type.

Table 2.
Comparison of time efficiency of transport mode and patient outcome

Transport Mode	Survived	Died
Most Time Efficient	512	32
Less Time Efficient	186	10

* p=0.569; OR= 0.81, 95%CI 0.39 to 1.68

There were 42 deaths in this sample as illustrated in table 2. Ten were in the group that was transported by the less time efficient transport mode (24%) and 32 were in the group that was transported by what was considered to have been the more time efficient mode of transport (76%). There was no statistical difference between the groups (p=0.568; odds ratio 0.81 with 95% confidence interval 0.39 to 1.68).

Figure 4 shows the geographic distribution of all crashes by transport mode and patient outcome (i.e., lived or died). The triangles represent those patients who were transported by HEMS with red representing the patients that died and pink the patients that survived. The squares represent those patients who were transported by ground ambulance with dark blue representing the patients that died and light blue the patients that survived. As before, the yellow area on the map indicates the general regions in the county where it was more time efficient to transport a patient via ground ambulance.

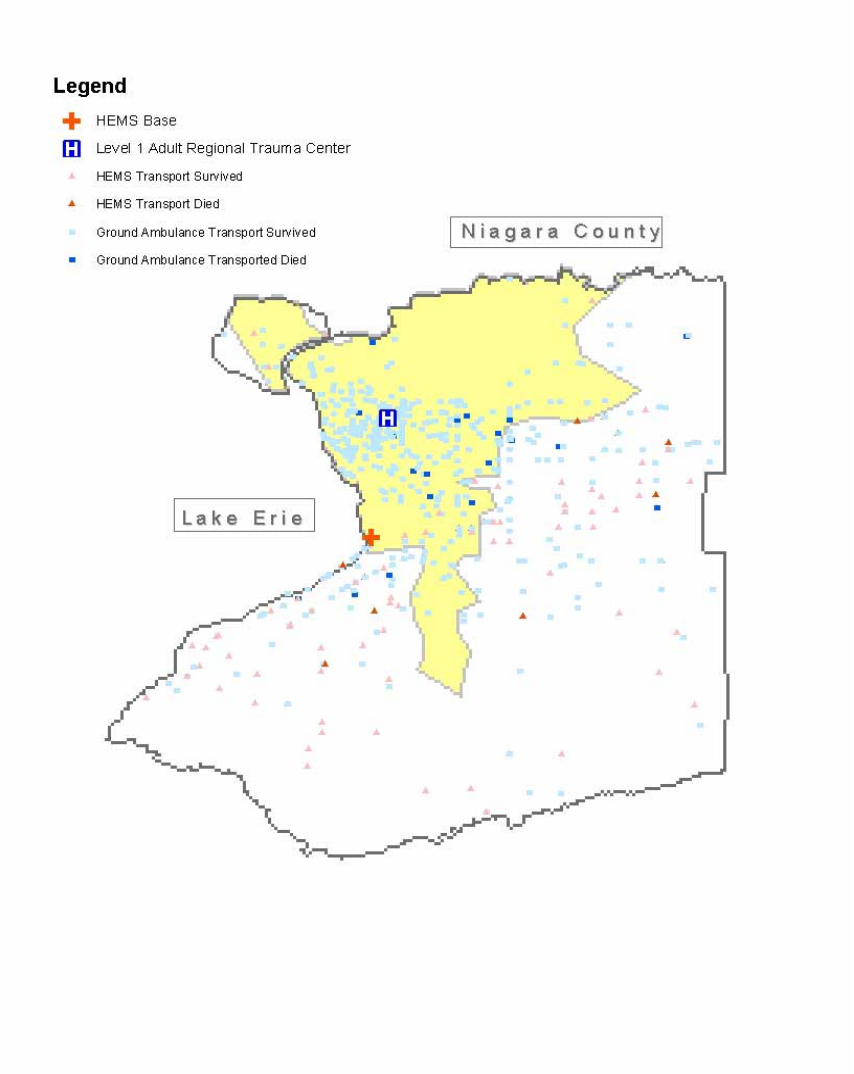

Figure 4. Outline of Erie County with the area where it is more time efficient to transport by ground ambulance shown in yellow. Motor vehicle crash locations are shown by transport type and vital status.

If total prehospital time for helicopter transports could be decreased by 5 minutes through the use of advanced ACN systems, we show in Figure 5 that the area where helicopter utilization was most time efficient would increase. The yellow indicates the areas that were originally identified as ground transport areas but are now more time efficient for HEMS transports. The green shows the area where it would still be more time efficient to transport by ground ambulance even with advanced ACN systems. Using the revised map, 55 additional patients would be transported from locations where HEMS transport would be more time efficient.

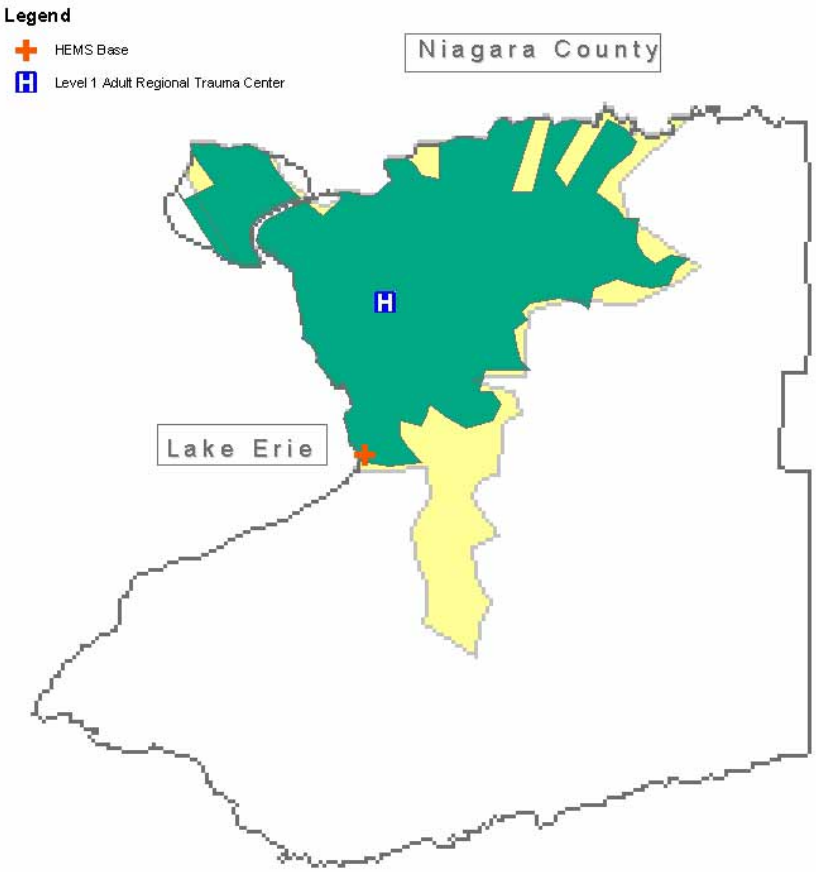

Figure 5. Outline of Erie County with the area where it is more time efficient to transport by ground ambulance shown in yellow. The green represents the reduction in the area that would result from widespread ACN use.

DISCUSSION

This study represents a first attempt at assessing the time-efficiency of transport choices made in Erie County. The data suggest that 26% of patients injured in a motor vehicle crash were not transported by the most time efficient means. The majority of these crashes involved ground transports from areas in which HEMS was identified to be the most time efficient mode of transport. However, the observed patterns of patient transport may have been influenced by other factors such as weather. This study was conducted in Western New York State in a county bordered by Lake Erie on the west and in close proximity to Lake Ontario on the north. In cases where ground ambulance was used instead of HEMS it may have been because the helicopter could not fly because of weather. In which case, the care provider did not make an inappropriate transport decision. Furthermore, some motor vehicle crashes may have resulted in multiple occupants being injured and requiring treatment at a level 1 trauma center. In these cases EMS providers would have had to decide which patient should be flown by HEMS and which patient should be transported by ground ambulance. Future studies should examine the effect of weather as well as provider decision making when more than one patient is injured at the same location.

It is also important to note that since the areas defining the most time efficient transportation modes were identified using retrospective data, it is possible that the specific circumstances of a given crash may have made the alternative form of transport more efficient. For example, in those crashes involving an entrapped patient who required a lengthy extrication, HEMS might have been the more time efficient transportation mode. This is because the helicopter could have arrived at the scene before the extrication activities were completed and then transported the patient at higher speeds and via a more direct route than a ground ambulance.

It is interesting to note that the majority of patients who expired were transported by the more time efficient mode of transport. However, this result was not statistically significant and could have been due to chance. Further, it is possible that EMS providers may have more rapidly transported patients they judged to be more severely injured and who ultimately died. Petri, Dyer, and Lumpkin found shorter on-scene times for patients who were more severely injured, and also found that patients with shorter on-scene times were more likely to expire.[8] These authors suspected that providers could identify those patients who would ultimately expire. This was supported by Emerman, Shade, and Kubincanek who found that when emergency medical technicians predicted patient mortality on a visual analog scale, they were as accurate as the Revised Trauma Score and two other measures of injury severity in predicting the patients' ultimate outcome.[9] Lastly, Simmons et al., found that using a four point scale similar to the subjective CUPS score used by most EMS providers, paramedic perception was an important indicator of patients who truly needed the interventions provided by a level 1 trauma center.[10] The findings of the current study may have been heavily influenced by providers ability to correctly identify those patients who would ultimately not survive. Future studies need to be performed with more patients so models can be built that control for injury severity. This would help determine the effect of using the most time efficient form of patient transport on patient outcome.

Lastly, this study found that if an advanced ACN system could help dispatchers identify motor vehicle crash occupants who would need treatment at a level 1 trauma center and could put HEMS on stand-by, the estimated 5 minute reduction in total prehospital time could increase the number of patients who should have been flown by 20%. However, these results may under-represent the number of patients who would be affected since we only estimated the timesaving of putting HEMS on stand-by. The timesaving could be greatly increased by actually dispatching HEMS to the scene of the crash when the original 9-1-1 request for aid is received. Figure 2 shows a representative EMS event timeline for a trauma patient. It illustrates that if a patient needs to be transported by HEMS the helicopter will not be dispatched to the scene until the first EMS agency has arrived on scene, evaluated the patient, determined HEMS is needed, and placed a request through their dispatch center. If the 9-1-1 dispatcher, ground ambulance dispatcher, or HEMS dispatcher could reliably use the information from the ACN system to identify that a patient needed rapid transport to a level 1 trauma center, then HEMS could be put on stand-by, or more aggressively, be dispatched to the scene at the time of the 9-1-1 request for aid (auto-launch). Data from FARS indicates that the national average elapsed time from crash notification to EMS arrival at the scene is on the order of 11 minutes.[11] Assuming two minutes to assess the scene and request HEMS would bring the total average elapsed time between notification and HEMS request to 13 minutes. If we assume that HEMS auto-launch could save approximately 13 minutes in total prehospital time, then our model indicates there would be a 40% increase in patients for whom HEMS would have been the most time efficient transport mode. Thus, ACN could play a much larger role in reducing total prehospital time

than was estimated in this study and would likely impact many more patients.

Limitations

Although there are simplifying assumptions inherent in the empirical approach used in this study, some general observations can be made which have merit. However, this study was limited by the fact that almost 50% of the registry patients could not be matched to police accident report data. Since most of the prehospital information for these patients was missing, it is possible that many of these patients were not injured in Erie County. It is also possible that these patients were injured in the towns that did not participate in the police accident report database. In any case, these missing patients could have introduced bias into the study but without further information, it is difficult to know the effect of that bias.

CONCLUSIONS

Seventy-four percent of patients in Erie County were transported by the most time efficient mode of EMS transport. There was no statistically significant difference in mortality between those transported by the most time efficient mode and those transported by a less time efficient mode. Our model indicates that the use of estimates of crash severity and potential occupant injuries from advanced ACN crash messages to place HEMS on standby would increase the area where HEMS transport would be more time efficient. This would have placed an additional 20% of patients in our study in the area where it was more time efficient to transport by HEMS. However, it is anticipated that ACN will provide greater reductions in total prehospital time that will result in HEMS being the more time efficient transport mode for greater numbers of patients.

ACKNOWLEDGEMENTS

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